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DOI: https://doi.org/10.1007/s10209-020-00719-6

Published in: Universal Access in the Information Society, published online 08 May 2020, doi 10.1007/s10209-020-00719-6

Between fascination and concern: An exploratory study of senior citizens' attitude towards different biotechnologies

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Abstract (250 words)

The present exploratory study describes senior citizens' attitudes relating to biotechnologies, which were compared with a younger sample. Using an anonymized voluntary paper-and-pencil survey, data were collected from a total of 86 senior Swiss adults attending the Seniors' University in Zurich, Switzerland. Unlike previous studies, our data suggest that senior citizens value the utility of biotechnologies. In particular, a high level of fascination was directed towards the prospects of medical biotechnological applications. Consistent with prior studies, our data reveal that senior citizens also express reservations in the face of potential risks. Therefore, an often-alleged conservative response-behaviour of this group only relates to the supposed harm of these technologies. To explore the response-behaviour of this cohort across technologies, we found a lesser degree of differentiation compared to university students. Consistent with this reduced level of differentiation, senior citizens assessed agricultural biotechnology similarly positively compared to nanotechnology and synthetic biology, in contrast to university students who made a clear distinction between positively evaluated emerging technologies and the more sceptically assessed agricultural biotechnology. Differences of gender were revealed to be more pronounced in case of senior citizens compared to students, indicating that a comparison between different societal subgroups can contribute to a wider understanding of factors influencing public technology assessment without introducing a rigid separation of these groups. We close by discussing consequences for public-policy making and science and technology communication, such as the need to emphasise the characteristics that demarcate technologies against each other in public communication for this and comparable groups.

Keywords: Biotechnologies; Attitude; Age; Senior Citizens; Public Understanding of Science; ELSI

1. Introduction

Innovation and progress in biotechnology are central aspects of the technological development in the early twenty-first century. They have enabled new methods of scientific research and the development of important multisectoral applications (e.g. health, agriculture, chemistry, energy, environment, etc.). Although biotechnology has the potential to significantly contribute to the solution of societal and environmental problems, it must be acknowledged at the same time that technological progress has caused some of the problems that should now be solved with new technological developments. Furthermore, every new technology comes with a risk of unintended side effects or abuse. Awareness of these limitations is reflected in the general decline of optimism towards nanotechnology (NT) and biotechnology observed in empirical studies (Gaskell et al., 2011). Accordingly, people often disagree on whether specific technologies should be promoted or prohibited. Moreover, research has shown that, for certain applications, there is a demand in society for rigorous debate about their implications and potential hazards (e.g. Frewer et al., 2004).

While there have been studies comparing the perception of emerging biotechnologies between experts and the public (Sjöberg, 2004), there are only scarce data on specific subgroups within the public. The putative degree of disagreement between different cohorts not only informs us about the heterogeneity of the public but can also resolve some of the tensions that have been observed when studying the apparent dichotomy along an expert-lay dimension. In addition, a better understanding of peoples' reactions to specific technological innovation is pertinent for the assessment of technological acceptance and public-policy processes.

The data presented in this article are part of a larger study on attitudes of emerging biotechnologies. We previously reported detailed results of a young sample (Ineichen et al., 2017). Here we explore the perspectives in later adulthood using a smaller sample. Particularly for Western societies, the older adult population is the fastest growing segment. Medical progress, knowledge on health-related lifestyle choices, and improved social service providers have resulted in a current population

in which nearly one-fifth (18.1%) of people are 65 or older (Federal Statistical Office (BFS), 2016, Switzerland, 2016). Relative to the members of the comparatively young sample in the first part of the study (Ineichen et al., 2017) who grew up with controversial debates particularly on agricultural biotechnology (AGT), senior adults have witnessed a time without the apparent multisectoral effect of biotechnology. However, they are more vulnerable to illness and thus more likely to profit from technological progress in the near future. From the studies addressing age as a determinant for technology assessment, some created respondent profiles (George et al., 2014) and used correlations across one sample to investigate whether sociodemographic factors relate to the evaluation and acceptance of new technologies. Strict group comparisons aiming at unveiling attitudinal differences of age between two cohorts that transcend simple descriptive comparisons (e.g. Eurobarometer, 2005) seem to be less prevalent. In this study, the idea of comparing specific cohorts is based on an adjudged reasonableness to assume existing generational effects (Bourdieu, 1990). Because Bourdieu (1990) and colleagues have also questioned the notion of generation by emphasising that internal differences within a cohort could be much more important than the collective interests of an entire generation, a thorough investigation of two entirely separate groups offers the possibility to also uncover demarcating details within groups. Apart from revealing potential differentiating factors between groups, group comparisons can also reveal characteristics within groups.

Previous research investigating age as a determinant of the acceptability of biotechnologies has provided mixed results with some studies showing that age is not a significant factor (Siegrist, 2008). Zepeda and colleagues (2003) highlighted a non-linear relationship between opposition and age, and others showed that support normally drops with age, while the attribution of risks increases (Eurobarometer, 2005; Rousselière & Rousselière, 2017). Apart from these contrasting results that need clarification, senior adults represent a cohort that is frequently under-represented or excluded from quantitative research mainly due to difficult access to recruitment.

In this study, we examine senior citizens' opinion of biotechnologies and compare these results to our previous study with university students (Ineichen et al., 2017). More specifically, we address the following set of hypotheses:

General hypothesis H1: Senior citizens are a conservative cohort.

A common stereotype that is associated with senior adults includes the characterisation of elderly individuals as a conservative cohort (Brewer et al., 1981). They are also often typified as a cohort that has a propensity to look back at 'the good old times'. Consistent with prior research, older respondents were shown to be more conservative (e.g. Wang, 2017). Accordingly, an increased awareness for potential risks in the context of new and emerging products has been described (e.g. Rousselière & Rousselière, 2017). Given the general openness, acceptance, and positivism of young generations towards biotechnologies (Ineichen et al., 2017; Rousselière & Rousselière, 2017) and based on the presumed existence of generational differences, we assumed an older generation would express more risk-related concerns relative to young individuals. A recent study, for example, claimed that as age increases, biotechnologies are perceived as riskier, while the utility felt is not any greater (Rousselière & Rousselière, 2017). The authors therefore predicted that support for biotechnologies will decrease as age increases. Indeed, they found a significant effect of age in the analysis of the pooled Eurobarometer surveys from 1991 to 2010. More precisely, the authors found that the probability of being optimistic about biotechnologies and genetic engineering decreases from 56% at 20 years of age to 44% at 60 years (and to 37% at 80 years). Concerning genetically modified (GM) food, the authors found that the probability of support goes from 33% at 20 years to 27% at 60 years (and to 25% at 80 years). We thus hypothesised that a more senior population will demonstrate a more critical response behaviour towards the presumed harm of biotechnologies. Accordingly, we expect that a more conservative cohort will also be more hesitant to appreciate potential benefits from innovative biotechnological products. These expectations are supported by the comparison between other societal subgroups. Our previous work using data from university students showed that female students and students in humanities and social sciences, two groups

that generally attributed more risks to biotechnologies, also showed less appreciation of potential benefits (Ineichen et al., 2017). Because the absence of perceived utility is one of the determining factors of the opposition to biotechnologies regardless of the field of application (Amin et al., 2014; Auer, 2008; Einsiedel & Medlock, 2005; Gaskell et al., 2004, 2011; Klingeman & Hall, 2006; Marris, 2001; Pardo et al., 2009), we also expected that the lack of ascribed benefits leads to a request for a stricter degree of regulation by senior citizens.

Specific hypothesis H2: Medicine is an important topic for senior adults in the context of emerging biotechnologies.

Contrary to H1 (senior citizens are a conservative cohort within society), we hypothesise that the presence of health-related problems that are partly linked to ageing could drive senior citizens to be more open to medical biotechnological innovation. Pardo et al. (2009), for example, underlined a greater acceptance of GM plants for obtaining a means to combat severe diseases, illnesses affecting children, and the effects of ageing. We therefore expect that, based on being in a different stage of life, senior adults will be particularly interested in medical biotechnological products. Therefore, senior individuals were predicted to assess medical biotechnological products more favourably compared to the younger cohort. With this study, we aimed at resolving the tension between the presumably conservative attitude of senior adults (H1) and an expected interest in medical biotechnological products.

General hypothesis H3: There is a decreased degree of differentiation of senior citizens.

We hypothesised that, in line with a lower degree of fascination and reduced biotechnology literacy conceptualised as antecedents of a more hesitant attitude (apart from the medical context) senior citizens might differentiate less between the technologies compared to university students and thus display a more uniform and invariant response behaviour. The assumption that senior citizens are generally less likely to use (consume) emerging technological developments favours the adjudged lower degree of interest and fascination, thereby driving a lower degree of differentiation. For

instance, stereotypical purchase behaviour of traditional and known products may corroborate this assumption. A better understanding of the degree of differentiation is expected to be useful for both a more nuanced public-policy making as well as science and technology communication.

Specific hypothesis H4: Agricultural biotechnology is the most critically assessed technology.

In our previous study with university students, AGT was the technology that was most critically assessed compared to NT and synthetic biology (SB) (Ineichen et al., 2017). In line with H1 and given that senior citizens have witnessed the emotional beginning of the debate about AGT as adults, whereas AGT is a rather conventional type of biotechnology for today's students compared to NT and SB, we thus expect that senior citizens will assess AGT even more critically. This however stands in marked contrast to the expectation of a lower degree of differentiation in H3. Either senior citizens do differentiate between technologies similarly to the responses collected from our students' sample with AGT demonstrating the most critically assessed technology or a putative lack of differentiation will abolish the observed resentment against AGT. Similarly, a lack of differentiation would also deflate the specific interest in medical biotechnology products hypothesised in H2. The aim of this strain of research is therefore to identify the correct hypotheses.

Based on the establishment of what has become a paradigmatic approach in risk perception, the psychometric model (Fischhoff et al., 1978), emphasising that the public's perception of risk is driven by emotional reactions (or gut feelings), we set out to compare emotional, implicit responses as opposed to more explicit, deliberate ones. We have applied this methodology in our previous study focusing on university students (Ineichen et al., 2017). Accordingly, in this article, we present data on spontaneous intuition towards SB, NT, and AGT compared to more deliberate assessments. In addition, we explore assessments on how the technologies should be regulated.

2. Materials and Methods

The presented data comprising responses of senior citizens are part of a larger study on attitudes of emerging biotechnologies. We collected data from the same survey that was previously used in a

study conducted with students from the University of Zurich and the Federal Institute of Technology (ETH) Zurich (Ineichen et al., 2017). The data presented in this article aim at providing an indication of how the detailed results of university students compare to an older segment of the population. It represents an exploratory study with a smaller sample of senior citizens. Due to their characterization of a high educational level, university students are not representative for the general population. To select for senior citizens with a comparably high educational background who are at the same time interested in ongoing scientific developments, we collected data from senior citizens attending the Seniorenuniversität Zurich, Switzerland (Seniors' University). The Seniors' University offers opportunities for senior citizens to attend presentations by researchers of the university covering a broad spectrum of topics. Members of the Seniors' University can thus be characterised by a particularly pronounced engagement in educational and social activities. Using an anonymised voluntary paper-and-pencil survey, data were collected from 86 men and women aged 59–87. We presented the study aims and significance of the project in two sessions on September 24th, 2015 and April 14th, 2016, before lectures of the Seniors' University Programme at the University of Zurich with approximately 400 older adults attending the first lecture, and 200 for the second one (approx. response rate: 14.3%). Upon presentation of the study goals and significance of the project, senior citizens were invited to pick up an anonymised voluntary self-completion survey, including a pre-paid return envelope, which was designed based on our previous study (Ineichen et al., 2017).

The questionnaire included three parts. First, we assessed demographic variables including occupational field, gender, and year of birth. In the association task, we presented participants with a list of characteristic items and asked them to spontaneously underline as many items (associations) as they wished that in their opinion relate to the different technologies. They were asked to perform this task speedily as if time were limited. The order of items and technologies was randomised across participants. Items were chosen based on a review of the literature, media consultation, and discussion among people of the research group. We explored participants' explicit assessment of

statements (i.e. characteristic deployment examples) with regard to their benefit and harm potential and probability (5-point Likert scale evaluation), followed by a task in which participants had to decide about the appropriate degree of regulation (4-point Likert scale evaluation). The deployment examples used in the study were pre-tested among experts working in the fields of SB and NT (see Ineichen et al., 2017). Statements were presented one after the other in a 3x2x2 design: each technology x 2 conditions: effects on environment and humans relating to potential harm and benefits. Informed consent was obtained by participants prior to performing the survey. Respondents could quit the survey at any time. The study was exempt from ethics review by national regulation.

We conducted a descriptive statistical analysis using SPSS Statistics 24.0, complemented by inferential statistics including the Mann-Whitney U test, Friedman two-way factorial analysis of variance, Pearson's $\chi 2$, Kruskal-Wallis test, and paired-sample t-test. Significance was accepted at a $p < 0.05$ level.

3. Results

3.1. Descriptive Analysis of Sample

We analysed the responses of 86 senior citizens (55% female, mean age: 68.6 years, Table 1) and compared them to our previous sample consisting of 1474 students (46.1% female; mean age: 23.8 years) (Ineichen et al., 2017). Moreover, nearly one-third of the members of the Seniors' University Programme hold a university degree. The cohort still represents a diverse group with 53% having obtained an apprenticeship diploma as a highest school certificate (Table 1). When asked which scientific discipline corresponds best with their field of work or their way of thinking, responses were evenly distributed among engineering, medicine, and social sciences with people selecting natural sciences representing the smallest group (14%). None of the participants provided an answer that did not fit in any of the four categories.

Table 1: Demographics of the respondents (n = 86)

Mean age [years]	Respondents	69
Gender [%]	Female	54.7
	Male	45.3
Professional background [%]	Natural sciences	13.9
	Health/medicine	29.1
	Humanities and social sciences	27.8
	Engineering	29.1
Highest educational degree [%]	Apprenticeship	52.9
	Higher school certificate	17.6
	University degree	29.4

3.2. *Comparison between Senior Citizens' and University Students' Assessments of Biotechnologies*

In the following sections, we compare the responses of senior citizens with a sample of university students that has been used previously (Ineichen et al., 2017). The sample consisting of senior citizens answered to the exactly same questionnaire that was distributed to university students several months earlier.

3.2.1. Spontaneous responses towards biotechnologies

Implicit reactions of senior citizens towards biotechnologies were collected through participants' selection of predefined items. Items were classified prior to study as being either positively or negatively connoted. In the mean, the aggregate attribution rate of positive items was 40% in the case of NT (Stud: 49%), 36% in the case of AGT (Stud: 37%) and 34% in the case of SB (Stud: 38%). On the other hand, the mean attribution rate of negative items was 16% in the case of AGT (Stud: 13%) followed by 15% in the case of SB (Stud: 8%) and 13% in the case of NT (Stud: 7%). These results

indicate that more positive than negative items were selected by both subgroups and that larger intergroup differences appear on the negative compared to the positive side.

For the comparison of the two samples, we conducted a non-parametric Mann-Whitney U test and found significant differences between the two groups for all three investigated technologies (see Fig. 1 for specific effects of group on the selection frequency of items). Interestingly, NT revealed the highest number of significant differences (n = 11 items) followed by SB (n = 6) and AGT (n = 2). The previous comparison also reveals that the highest degree of similarity between groups pertains to intuition concerning AGT. The selection frequency of 'risky', 'dangerous', and 'uncontrollable' significantly differed in the cases of NT and SB with senior citizens demonstrating a higher selection frequency towards these items (NT_{risky}: U = 77493.00, p = .000, SB_{risky}: U = 76491.00, p = .000; $NT_{dangerous}$: U = 76057.00, p = .000, $SB_{dangerous}$: U = 70296.00, p = .003; $NT_{uncontrollable}$: U = 68939.00, p = .009, $SB_{uncontrollable}$: U = 70511.00, p = .002; Fig. 1). There was no significant difference of group for these items in the case of AGT. The absence of any difference of group for these items in the case of AGT is due to an increase in the selection frequency by students rather than a decrease by senior citizens. Consistently, 'scary' and 'soulless' revealed the same differences, with senior citizens demonstrating a higher association frequency than university students for all investigated technologies (AGT_{scary}: U = 58495.00, p = .05, NT_{scary}: U = 69068.00, p = .007; SB_{scary}: U = 72126.00, p = .000; $AGT_{soulless}$: U 66735.00, p = .006, $NT_{soulless}$: U = 66471.00, p = .004, $SB_{soulless}$: U = 70561.00, p = .000; Fig. 1). Together, these results reveal a consistently increased intuitive perception of negative items of senior citizens towards emerging biotechnologies relative to university students. On the other hand, senior citizens adjudged high levels of fascination and apparently hold great promise for the future of emerging biotechnologies (NT and SB). There were no consistent differences of group concerning positive items in contrast to the tendency observed for negative items.

Fig. 1: Mean values of the selection frequency of items with senior citizens as the level of comparison (sorted in decreasing order) for agricultural biotechnology, nanotechnology, and synthetic biology. Left panel (blue background): positive items, right panel (orange background): negative items. Asterisks pertain to significant differences between the two groups.

Next, we performed a descriptive analysis to investigate the effects of gender on the spontaneous selection of items. We found a greater difference between male and female senior citizens than between female and male university students for positive and negative items throughout all investigated technologies (see Fig. 2). As a side note, we observed a tendency regarding a split along the gender dimension for positive items with respect to all three technologies. Males (students and senior citizens) seem to have spontaneously selected positive items for biotechnologies more frequently compared to females. For negative items, however, the group membership relevant for the characterisation of biotechnologies appears to have changed from gender to age in the case of NT and SB. In other words, responses concerning negative items for NT and SB were more similar within age groups than within gender groups.

Fig. 2: Mean values of the selection frequency of items with female senior citizens as the level of comparison (sorted in decreasing order) for agricultural biotechnology, nanotechnology, and synthetic biology. Left panel (blue background): positive items, right panel (orange background): negative items.

To investigate the degree of differentiation across technologies between the two subgroups, we conducted a Friedman two-way factorial analysis of variance for the positive and negative items. As expected (H3), there were less significant differences of item attribution across technologies for

senior adults compared to university students (particularly in the case of negative items; data not shown).

3.2.2. Considered assessment of biotechnologies

After the spontaneous responses in the implicit task described in the previous section, we now describe the more considered harm-benefit assessments of characteristic applications of AGT, NT, and SB for human well-being (e.g. in medicine, clothing, or nutrition) as well as for environmental protection. On an aggregate level, more benefits (mean: 3.2 on a 4-point Likert scale) than harm (mean: 2.7 on a 4-point Likert scale) were assigned to the technological deployments. The same is true for the probability of occurrence; participants ascribed a higher probability towards the occurrence of envisaged benefits (mean: 3.2 on a 4-point Likert scale) relative to harm (mean: 2.9 on a 4-point Likert scale; see Fig. 2). Note that 'no-opinion' was excluded as an answer option for these analyses and that, strictly speaking, direct comparisons of different deployment examples depend on contextual factors of the presented example and therefore should be taken with caution.

In the second step, we wanted to explore the effects of the group on the explicit opinion of study participants and technology applications. For this purpose, we conducted a non-parametric Mann-Whitney U test (Fig. 3). These results were validated by performing a Pearson's $\chi 2$ test to establish associations between groups and respondents' assessments of characteristic deployment examples (see Supplementary Online Resource 1). Consistent with the implicit task, the comparison of deliberate assessments of characteristic deployments and group revealed significant differences pertaining to harm rather than the benefit assessment. Again, we observed that senior citizens see more harm potential than university students throughout all technological applications (Fig. 3). In contrast to the implicit results, the most pronounced effect of group pertains to consequences of AGT for humans. The analysis of the potential benefits revealed a similar response behaviour of the

two groups with a single significant difference pertaining to SB applications for the human context which senior citizens adjudged more beneficial.

Fig. 3: Mean harm and benefit ratings of a 4-point Likert scale with sorted deployment examples (for the Pearson's χ2 test results, see Supplementary Figs. Online Resource 1 and 2). Top: Harm and benefit potential, bottom: harm and benefit probability of occurrence; mean rank of statement evaluation between groups; significant MW-U test results of ***left upper panel:*** U = 69478.50, p = .038; U = 86876.50, p = .000; U = 70671.00, p = .007; U = 70482.50, p = .006; U = 72417.00, p = .000; U = 63422.00, p = .005; ***right upper panel:*** U = 63222.00, p = .047; ***left lower panel:*** U = 69177.00, p = .002; U = 49672.00, p = .014; U = 68158.50, p = .000; U = 57102.00, p = .045; ***right lower panel:*** U = 46873.00, p = .026; U = 68748.00, p = .000; U = 61875.00, p = .022.

Besides the harm and benefit potential of characteristic deployments, we also enquired about the probability of occurrence because the differentiation between potential and probable occurrence is often useful to attain a better understanding of risk perception. While a specific deployment may be assessed as very harmful, its probability of occurrence may be assessed as negligibly small (or vice versa). Regarding the evaluation of the probability of occurrence, again the benefit probability was selected at a higher degree than the harm probability (mean: 2.9 for harm probability and 3.2 for benefit probability). In the case of AGT (human context) and SB (both contexts) for harm probability as well as AGT (human context) for benefit probability, we found the same characteristic response behaviour with senior citizens adjudging a higher probability of harm and students assigning a higher probability of benefit (for the Pearson's χ2 test results, see Supplementary Online Resource 2). Contrary to these consistent results, the assessment of harm probability of NT applications (environmental context) and the assessment of the benefit probability of SB (both environmental

and human context) show a reversed pattern in that senior citizens adjudge a lower harm and higher benefit probability compared to their student counterparts (Fig. 3).

To investigate the degree of differentiation, we compared the response behaviour of participants between the assessments applying to the same valence dimension. More specifically, we conducted a series of paired-sample t-tests to test for dissimilarity between the probability of occurrence and the potential of harm or benefits. As in the context of the implicit task, the results again revealed less differentiation of senior citizens compared to university students (data not shown).

In addition, we were interested in comparing the two groups with respect to differentiation between the technologies. We therefore conducted a Friedman's two-way ANOVA by ranks. Again, the results revealed a more uniform response behaviour of senior citizens across all investigated examples (in particular in the case of the probability assessment, data not shown).

Next, we were interested in gender effects on the response behaviour of our sample. A Kruskal-Wallis testing the effects of gender revealed that senior females represent the most critical group and that there were significant differences across groups for every evaluation of the respective harm potential. Because we were only interested in the main effects of group, we refrained from outlining the respective pairwise comparisons within the main text (for specific results see Fig. 4). In contrast to the results that we found in our survey on university students, the results for senior citizens revealed no significant gender differences in the case of the benefit potential. Consistent with the descriptive results obtained from both the negative and positive items of the implicit task, male and female senior citizens differ to a larger degree when assessing the danger potential compared to male and female university students.

Fig. 4: Mean harm and benefit potential ratings of a 4-point Likert scale with sorted deployment examples. Top: Harm and benefit potential, bottom: harm and benefit probability of occurrence. Harm potential: significant differences pertain to ***AGT-Maize:*** *senM-senF*; *studM-studf*; *studM-senF*;

studF-senF; ***AGT-Soy:*** all except *studF-senM*; ***Nano-Sunscreen:*** *studM-studF*, *studM-senF*; ***Nano-Packing:*** all except *senM-studM*, *senM-studF*; ***SB-Bioind:*** *studM-studF*, *studM-senF*, *studF-senF*; ***SB-CL:*** *studM-studF*, *studM-senF*, *studF-senF*. Benefit potential: no significant differences.

3.2.3. Comparing the desired degree of regulation

Finally, participants were asked to select the degree of regulation they consider appropriate for the technology in question. In the mean, the aggregate sample selected similar regulation requirements for the different technologies. A comparison to investigate the effect of group on the level of regulation revealed one significant result in the case of AGT (MW-U test: $U = 235776.50$, $p = .001$) where senior citizens surprisingly opted for a less strict type of regulation than students (Fig. 5). Again, these results were validated by performing a Pearson's $\chi 2$ test to establish associations between groups and respondents' assessment of characteristic deployment examples (see Supplementary Online Resource 3) This outcome goes against prior studies demonstrating older individuals wanting more regulation (e.g. Wang, 2017). There is otherwise no tendency reassuring that senior citizens are less strict.

Fig. 5: Comparison of the level of regulation as assessed by senior citizens and university students. Increased levels of regulation pertain to stricter forms of regulation (for Pearson's $\chi 2$ test results, see Supplementary Online Resource 3).

4. Discussion

This study examined the attitudes of senior citizens towards AGT and emerging biotechnologies and compared the results with a younger population. In the following, our results are being discussed with respect to the hypotheses suggested at the outset.

4.1. Senior Citizens as a Putatively Conservative Cohort (H1)

Building on the characterisation of people in later adulthood as a conservative sample in attitudes towards biotechnologies (Brewer et al., 1981; Wang, 2017), we hypothesised that senior citizens would ascribe a higher harm potential to common deployment examples. This hypothesis is in line with prior outcomes showing differences between more and less critical subgroups in the population, for instance a more critical attitude among female students and students from humanities and social sciences, as opposed to male students from natural sciences. It would moreover reflect an already attested contrast to the optimistic stance that has been documented in the case of younger individuals (Rousselière & Rousselière, 2017) and university students that reside in a more natural-scientific discipline (Ineichen et al., 2017). Consistent with previous studies, H1 also assumes that senior citizens are more hesitant to adjudge benefits, utility, and support to technological examples. Consistent with H1, the data reveal the expected increased ascription of harm by senior citizens (for NT and SB in the implicit task and for all examples in the explicit task).

Contradictory to H1, we observe a similar or even increased degree of support for all technologies compared to the younger cohort on three layers: senior citizens show a similar spontaneous selection of the numerically most important positive items, they judge the concrete benefits of biotechnologies as similar or even higher, and they opt for similar or even lower regulation. These study outcomes, albeit extracted from a relatively small sample, may challenge the adjudged conservatism of the investigated cohort.

According to the risk-utility dilemma (Gaskell et al., 2004; Klingeman & Hall, 2006, the perception of biotechnologies as risky is not compensated for in older Europeans by an increased perceived utility. This stands in marked contrast to the results that are presented here. While we indeed found that senior adults show an increased harm sensitivity compared to students, they unexpectedly show a similar response behaviour when ascribing benefits to technological deployments. They even surpass the students' ascribed level of benefits in one example. In addition, the implicit task offers some

insight in this respect. The term 'fascinating', for instance, is selected with the highest and second highest frequency by senior adults in the case of NT and SB, not providing evidence for less enthusiasm in this cohort.

By merging the data with our previous study (Ineichen et al., 2017), we found senior citizens' attribution of harm to be more similar to that of the students from humanities and social sciences. Contrarily, senior citizens' response behaviour concerning the ascription of benefits relates more to the assessment of students of natural sciences (Supplementary Online Resource 4). They therefore share the characteristics of the critical stance of students from social sciences and humanities combined with a generally optimistic stance of students from natural sciences with regard to the perceived utility of these technologies. Hence, the hypothesised characterisation of senior citizens as 'conservatives' does not do justice to the specificities of this group. Rather, senior citizens appear as a sensitive population concerning potential harmful consequences of new technological innovation that comes not at the expense of fascination, curiosity, and the promotion of biotechnology in general. In summary, both subgroups clearly share their conviction about the great potential of biotechnologies and there is evidence that it might not necessarily be correct to ascribe senior citizens a generally conservative attitude.

4.2. Medicine as a Major Topic for Senior Adults in the Context of Emerging Biotechnologies (H2)

Biotechnological innovation is partly geared towards improving medical interventions. Previous studies (e.g. Pardo et al., 2009) have underlined the importance of biotechnologically derived medication or treatments to fight diseases, illnesses affecting children, and the effects of ageing for people advocating for technological advance. Given the characteristics of the surveyed cohort, we hypothesised an increased interest in medical innovation (H2). Albeit exploratory in nature, we found evidence that confirms this hypothesis, for instance, with the result that the innovative prospect of SB fabricated antibiotics was associated with particularly high benefits. That senior adults even adjudged more benefits than university students to this example, an outcome that goes against the

higher ascription of benefits by young university students in other examples, corroborates the significance of medical products for senior adults. The fact that closed-loop medical approaches reached the lowest harm assessment for all technological deployment examples further substantiates the relevance of medical applications for senior adults. Given the exploratory character of this strain of research, more data are needed to more thoroughly investigate this hypothesis.

4.3. Evidence for a Decreased Degree of Differentiation (H3)

In line with a more hesitant attitude and a presumable lack of knowledge of, experience with, and fascination for emerging technologies, we hypothesised a lower level of differentiation in the evaluation of different biotechnologies (H3). Although we have indications that a low degree of fascination by senior adults can be refuted based on the last section, the present data consistently show a rather uniform response behaviour (i.e. lack of differentiation) of the investigated cohort. Not only does the analysis of the response behaviour of senior adults applying to the selection of items (implicit task) strengthen this hypothesis but also the assessment of relevant deployment examples between and within technologies (explicit task) may demonstrate a reduced level of differentiation. More precisely, we found a consistently lower level of significant differences (1) in item selection across technologies on the implicit level, (2) on the explicit level when comparing probability vs potential estimations of the same application examples, and (3) across technologies (particularly in the case of the harm assessment). There is no tension between this result and H2 because the lack of differentiation (H3) concerns a comparison within responses of senior citizens, while the specific interest in medical products (H2) could be corroborated by a comparison to the student cohort: SB fabricated antibiotics is the only example for which senior citizens ascribed more benefits compared to university students. The benefit ascription towards this example in relation to the other examples (within senior citizens) was, however, not statistically different, thereby strengthening H3. The lack of

differentiation may lead to a generally more beneficial assessment of the utility of biotechnological deployments.

Given the high degree of enthusiasm towards biotechnologies by senior citizens and comparable levels of knowledge between the senior and student cohort as assessed by a brief knowledge task (see Supplementary Online Resource 5), the main driving factors for the observed invariant responses could not be isolated. More studies are needed to identify putative factors (not controlled for in this study) that lead to a lack of differentiation.

The phenomenon of a weaker degree of differentiation of senior citizens could help to integrate some of the mentioned findings. For example, the identified reversed pattern in the case of SB's harm and benefit probability ascription (lower harm probability and higher benefit probability ascribed by senior citizens compared to students) is likely caused by such a lack of discrimination rather than deliberate convictions. Likewise, the lower harm probability assigned by senior citizens to nano sunscreen can be explained with the reduced differentiation level compared to the student group.

That senior citizens may be characterised as the less discriminative population of the public has major consequences for public-policy making. Given the indistinguishability of the investigated technologies as assessed by senior citizens, public-policy making and science and technology communication should focus on emphasising the main differential factors that demarcate technologies against each other. This could allow the inclusion of the public in a more differentiated assessment and the development of regulation that considers the specificities of different technologies.

4.4. Agricultural Biotechnology as the Most Critically Assessed Technology (H4)

Based on our previous research (Ineichen et al., 2017), we expected AGT to represent the most critically assessed technology (H4). Contrary to this hypothesis, we found no general tendency for an above-average critical stance of senior citizens towards AGT in the implicit task. More precisely, the

selection frequency of positive items was even higher for AGT than for SB. The selection frequency of negative items was comparable to the one directed towards SB. To some extent, this result may again be explained by H3. While students evaluated SB and NT much more positively and less negatively than AGT, senior citizens evaluated the two emerging technologies more similarly to AGT, consistent with the found lack of differentiation. More precisely, AGT was the technology where associations were selected with the most comparable frequency between students and senior citizens. Unlike the comparable assessment reflected in the implicit task, there was a clear separation between students and senior citizens in the case of AGT's explicit harm assessment, where senior citizens assigned a higher harm potential and probability. There was however no difference in the ascription of benefits between the two groups. Taken together, except for the higher harm ratings of senior citizens in the explicit task, senior citizens not only show a decreased aggregated negative item selection for AGT but they also asked for the less stringent degree of regulation. In this request, they appeared even less restrictive than university students.

4.5. Effects of Gender on the Ascription of Harm and Benefits

Finally, the investigation on the effects of gender was conducted without hypothesis. We generally detected females to be more critical than males, consistent with the results of the previous study (Ineichen et al., 2017). Interestingly, the difference in spontaneously selecting characteristic items and the deliberate assessment of the danger potential of characteristic technology deployments between male and female senior citizens has been shown to be much greater than the difference between female and male university students, revealing a higher level of heterogeneity within this more experienced cohort.

In addition, we were able to identify a tendency of clustering along group membership of age or gender, depending on the response behaviour of spontaneous associations. More precisely, we observed a difference on group classification depending on the selection of positive relative to negative items with gender representing the classification variable in the case of positive items

(males with more positive attitude) and age representing the classification variable in the case of negative items (older adults with more negative attitudes). This tendency however pertains more to the emerging biotechnologies (SB and NT) and not to AGT, where the segregation is found along the gender dimension entirely.

Together, the results of the gender effects corroborate the usefulness of group comparisons for investigating the diversity between and among groups. It offers the possibility to uncover the specificities that underlie attitudinal characterisations of subgroups. It also indicates that a comparison between different societal subgroups can contribute to a wider understanding of factors influencing public technology assessment without introducing a rigid separation of these groups. Instead, age is understood as one factor, among many others, that can affect technology assessment (see 'Limitations').

5. Conclusions

In this exploratory study, we present data on attitudes of senior citizens regarding biotechnologies. Comparisons on attitudinal differences on biotechnologies are drawn against the background of a population comprising university students. Albeit senior citizens live up to one of the implicit stereotypes characterising them as conservatives, the data reveal that a more hesitant attitude comprises questions directed to potential harm only. Quite the contrary, an enthusiastic attitude relates to questions that include the alleged benefits and utility of biotechnologies and, in particular, medical biotechnological applications. Based on their uniform response behaviour over different (bio)technologies, senior citizens appear to be less discriminative, which affects public-policy making. When approaching this or a similar cohort, public-policy making and science and technology communication should focus on emphasising the main differential factors that demarcate technologies against each other. Consistent with the observed decreased degree of differentiation, and contrary to previous results, senior adults assessed agricultural biotechnology similarly positively to nanotechnology and synthetic biology. Strikingly, the effects of gender revealed a greater

difference between male and female senior citizens compared to female and male university students for positive and negative items throughout all investigated technologies. The data revealed an unexpected tendency regarding a fractionation of the sample, depending on the selection of positive relative to negative items with gender representing the classification variable in the case of positive items and age representing the classification variable in the case of negative items. The study thus indicates that a comparison between different societal subgroups can contribute to an improved understanding of factors influencing public technology assessment without introducing a rigid separation of these groups. Instead, age is understood as one factor, among many others, that can affect technology assessment.

6. Limitations

The participants in this study were recruited via the continuing education programme for seniors of the Seniorenuniversität Zurich. A high level of education and social participation in cultural and social activities can be attributed to the members of the before mentioned programme which implies that our sample is rather a selected part of the ageing population and therefore not fully representative. In particular, the sample is relatively small and composed of participants from a single center and country. Based on the small sample size, the statistical analyses lack typical multivariate techniques. Compared to the cohort consisting of university students, the present cohort shows, however, a higher degree of variance with regard to educational background. A follow up including a larger sample should therefore be performed to validate the results obtained in this exploratory study.

Based on the low response rate of 14.3% it must be assumed that there is a substantial group of older adults outside the study with a more (or less) critical perspective towards emerging biotechnologies and that only those that have a special interest in emerging biotechnology have actually participated.

Finally, to assess the direct effect of sociodemographic factors, the effect of age would be better explained by simultaneously considering cognitive and affective factors that influence technology

perceptions. One should therefore be cautious against relying on factors such as age solely to assess attitudes towards biotechnologies. Age and other sociodemographic variables are rather mediated through other sociocultural factors, such as knowledge of science, trust, attitude towards science in general, or media exposure and therefore should be examined as moderating factors that influence the strength of other antecedent factors. Despite these limitations, this study provides a first set of data relating to attitudes towards emerging biotechnologies in later adulthood.

7. Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

8. Acknowledgments

The authors would like to thank the Seniorenuniversität Zurich for the possibility to conduct this study and its members for participation. This publication is supported by the Swiss National Science Foundation as part of the NCCR Molecular Systems Engineering.

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10. Supporting information captions

Online Resource 1: Harm- and benefit ratings of a 4-point Likert scale reflecting the Pearson's $\chi 2$ test results.

Online Resource 2: Harm- and benefit probability ratings of a 4-point Likert scale reflecting the Pearson's $\chi 2$ test results.

Online Resource 3: Assessment of degree of regulation based on a 4-point Likert scale evaluation reflecting the Pearson's χ2 test results.

Online Resource 4: Harm- and benefit ratings of a 4-point Likert scale reflecting the Pearson's χ2 test results among senior citizens compared to students from humanities and social sciences and students from natural sciences.

Online Resource 5: Comparison of participants' knowledge about (bio)-technologies by means of a simple knowledge-task. Q1 (AGT): Genetic modifications of plants (single or few genes of other organisms (e.g. bacteria) are being introduced); Q2 (SB): Genetic modifications, where not only single genes but whole systems of genes that work together (i.e. circuits) are introduced; Q3 (SB): DNA synthesis plays a particularly important role; Q4 (NT): Work is performed with minutest, for the human eye invisible molecules; Q5 (NT): New materials are being produced; Q6 (AGT): Has, among others, the yield increase in the agriculture as a primary objective. Q1-6 were randomized across participants (and were freely translated into English for publication). The y-axis pertains to % of correct responses. A Pearson's χ2 test revealed no significant differences between groups.